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Discussion of Importance Index in Technology Foresight

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Jiayu CHENG

National Research Center for Science and Technology for Development
Ministry of Science and Technology of the People's Republic of China

Science and Technology Foresight Center
National Institute of Science and Technology Policy (NISTEP)
Ministry of Education, Culture, Sports, Science and Technology (MEXT)

This discussion paper has been prepared for use in discussion within NISTEP and for soliciting opinions from related researchers. The opinions expressed in this discussion paper are solely of the authors.

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Ministry of Education, Culture, Sports, Science and Technology (MEXT)

1-3-2, Kasumigaseki, Chiyodaku, Tokyo 100-0013, JAPAN

TEL: 03-3581-0605　FAX: 03-3503-3996

Contents

Discussion of importance index in technology foresight

Technology foresight has been adopted in many countries since the beginning of 1990s. Through assessment and analysis of importance and realization time of various technologies, it gives an indication of the direction and objectives of research and development, and provides the basic data for the promotion and development of science and technology. The importance index is one of the major indicators in technology foresight survey of Japan, Germany, Korea, China and other countries. In international comparativeness, the considerable differences, originating in each nation's socioeconomic circumstance, have been quantitatively shown to exist with respect to how each nation assesses the importance of various technologies[1]. In some countries, technology foresight strangely linked to the policy making, especially the priority setting, so the importance index should be discussed in detail.

1. Introduction

In Japanese fifth, sixth and seventh technology foresight report, the importance index was calculated by the formula,

$$I_{index}=(100*N_{high}+50*N_{medium}+25*N_{low})/N_{all} \quad (1)$$

Where N_{high}, N_{medium}, N_{low} are the number of responses indicated high, medium, low importance respectively and N_{all} is the total responses. Where all responses indicated "high" importance the index is 100, and where all indicated "unnecessary" it is 0.

The formula can be improved by considering the degree of expertise, and the comparativeness of the topics in different fields should also be discussed in more detail.

First, some restrictions existed in the formula. In Delphi survey, there were more then 10-technology fields, such as 16 fields in Japan's seventh survey, 15 fields in Korea's second survey, etc. The expert in each field needs to answer the questions of about 100 topics, with some of which he/she was familiar and the others was not. The statistical data shown that high, medium and low degree of expertise in top 100 importance topics of Japan's seventh survey shared the percentage of 15.1%, 28.9%

[1] Terutaka Kuwahara: *Technology Foresight in Japan - the Potential and Implication of DELPHI Approach-* the proceeding of international Conference on technology foresight, March 2001, Japan

and 56.0% respectively. It meant most of the responses couldn't understand the technical specifications sufficiently. In priority setting of special field, mainly specialists are involved as experts. But in broader foresight approach, the general or interested public were involved. In this case, we should consider the different contributions of the "experts", but it was not distinguished in formula (1), where the weighted value of high responses for all degrees was 100, medium was 50, and low was 25.

Secondly, the topic's importance in different fields was hardly used to make the comparativeness due to any topic meets special socioeconomic needs and the importance assessed by the different knowledge pool. In practice, even if two (or more) expert groups assessed the same topic, they always made the different opinions. There were some examples in Japan's seventh survey[2]. Typical example was for "Electronic Money", the importance degree was high in the technology supplier side of "Information and Communication (74)", but not very high in the technology user of "Distribution (45)", "Business and Management (52)", and "Services (57)". In this case, how to rank the topics?

From above discussion, three questions were raised when using formula (1).

(1) Was the topic's importance credible if the proportion of high degree of expertise was quit low?

(2) Should we consider the different contribution of expertise in calculating the importance index?

(3) Is there any way to replace the ranking? Generally, it is difficult to balance the opinions from different technology fields when aggregating all the topics.

The first and second questions will be discussed in importance index by considering the degree of expertise, and the third question discussed by introducing the relative importance index and grouping way of the priority topics.

2. Importance index by considering the degree of expertise

2.1 The formula

The importance index can be calculated by the formula

$$I_{index}=I_H*W_H+I_M*W_M+I_L*W_L \tag{2}$$

[2] NISTEP: *The Seventh Technology Foresight*, July 2001, P72-75.

Where I_H, I_M and I_L are the importance index of high, medium and low degree of expertise respectively, and W_H, W_M and W_L are the relative weighted values, where

$$W_H+W_M+W_L=1 \tag{3}$$

From formula (1),

$I_H=(100*N_{11}+50*N_{12}+25*N_{13})/T_H$

$I_M=(100*N_{21}+50*N_{22}+25*N_{23})/T_M$

$I_L=(100*N_{31}+50*N_{32}+25*N_{33})/T_L$

Where, N_{11}=Number of "High" responses with high degree of expertise

N_{12}=Number of "Medium" responses with high degree of expertise

N_{13}=Number of "Low" responses with high degree of expertise

$T_H=N_{11}+N_{12}+N_{13}+N_{14}$, is the total responses of high degree of expertise

N_{21}=Number of "High" responses with medium degree of expertise

N_{22}=Number of "Medium" responses with medium degree of expertise

......

N_{ij} show as fellows

Importance / Degree of expertise	High	Medium	Low	Unnecessary	Total
High	N_{11}	N_{12}	N_{13}	N_{14}	T_H
Medium	N_{21}	N_{22}	N_{23}	N_{24}	T_M
Low	N_{31}	N_{32}	N_{33}	N_{34}	T_L

2.2 Weighted values

As discussed in question (1) and (2), two factors should be considered in determining the weighted values.

(1) *The percentage of high, medium and low degree of expertise*

If the high degree of expertise (including medium) shared a large ratio of responses, the importance index was credible. In this case, the index can't be strangely influenced by the opinion of the low degree of expertise.

In another case, the low degree of expertise shared the high percentage of the responses; it meant few responses understood the topic and its importance was incredible. About 25% topics in top 100 important topics had less then 10% of high degree of expertise. These topics were probably in initial stage of research, and would make "breakthrough" in the future. Some topics closely related to the public life were indicated with the high importance, such as the first and second topics, related to the earthquake forecasting and the disposing of disused manufactured products, shared as high as 70% and 80% of low degree of expertise respectively.

(2) *The contributions of high, medium and low degree of expertise.* In general, the higher the degree, the greater the weighted value.

Combining with formula (3), the weighed values can be calculated by

$$W_H=K_1*T_H/T_{all}$$

$$W_M= K_2*T_M/T_{all}$$

$$W_L= K_3*T_L/T_{all}$$

Where K_i (i=1,2,3) called the convert coefficients, $K_1=1$ for high degree of expertise, K_2 for medium degree, K_3 for low degree, and $K_1 \geqslant K_2 \geqslant K_3$. Where $T_{all}= T_H+ K_2*T_M + K_3*T_L$, called the number of converted responses.

The formula of important index will be

$$I_{index}=(100*N_{11}+50*N_{12}+25*N_{13}+ K_2(100*N_{21}+50*N_{22}+25*N_{23})+ K_3(100*N_{31}+50*N_{32}+25*N_{33}))/ T_{all} \tag{4}$$

In formula (4), if $K_1=K_2=K_3=1$, the coefficient matrix of N_{ij} (i=1,2,3, j=1,2,3) show as fellows

Importance / Degree of expertise	High	Medium	Low
High ($K_1=1$)	100	50	25
Medium ($K_2=1$)	100	50	25
Low ($K_3=1$)	100	50	25

(This formula was used in Japan's survey. It means that the high, medium and low degree of expertise have the same contribution to the importance.)

If $K_1=1$, $K_2=0.75$, $K_3=0.5$, the coefficient matrix

Degree of expertise \ Importance	High	Medium	Low
High (K_1=1)	100	50	25
Medium (K_2=0.75)	75	37.5	18.75
Low (K_3=0.5)	50	25	12.5

(It means the contribution of high degree of expertise is greater then the others, and the medium degree is greater then the low degree. The high degree is as twice as low degree.)

If K_1=1, K_2=0.5, K_3=0.25, the coefficient matrix

Degree of expertise \ Importance	High	Medium	Low
High (K_1=1)	100	50	25
Medium (K_2=0.5)	50	25	12.5
Low (K_3=0.25)	25	12.5	6.25

(It means the contribution of high degree of expertise is as twice as medium degree, and as four times as low degree. The medium is as twice as low degree)

If K_3=0, it means the opinion of low degree of expertise was not included.

2.3 Convert coefficients K_i

The formula of importance index varies with K_i values. To determine the suitable K_i in (4), 46 topics with high percentage of high and medium degree of expertise, greater then the average value (44%), were selected from top 100 important topics, called the standard topic group. In this group, the rank by their importance was standard when K_3=0.

The importance index were calculated by six kinds of K_i in standard topic group (Appendix 1). As a standard rank in K_1=K_2=1 and K_3=0, other five ranks were compared by the order difference of the same topic. Statistical data indicated that the total difference was minimum (46) in K_1=1, K_2=0.5, K_3=0.25 if all the responses included (Table 1), where 41% topics had the same rank with the standard, 35% topics differed 1 order, and the maximum difference was 6 (Fig.1)

Table 1 Rank comparing by six kinds of K_i

	Order Difference					
	($K_1=K_2=K_3=1$)	($K_1=K_2=1$, $K_3=0$)	($K_1=1$, $K_2=0.75$, $K_3=0.5$)	($K_1=1$, $K_2=0.75$, $K_3=0$)	**($K_1=1$, $K_2=0.5$, $K_3=0.25$)**	($K_1=1$, $K_2=0.5$, $K_3=0$)
Total	126	Standard	80	36	**46**	76
Maximum	14		11	3	**6**	10

All respondents if K_3 not equal to 0, and only respondents of high & medium degree of expertise if $K_3=0$.

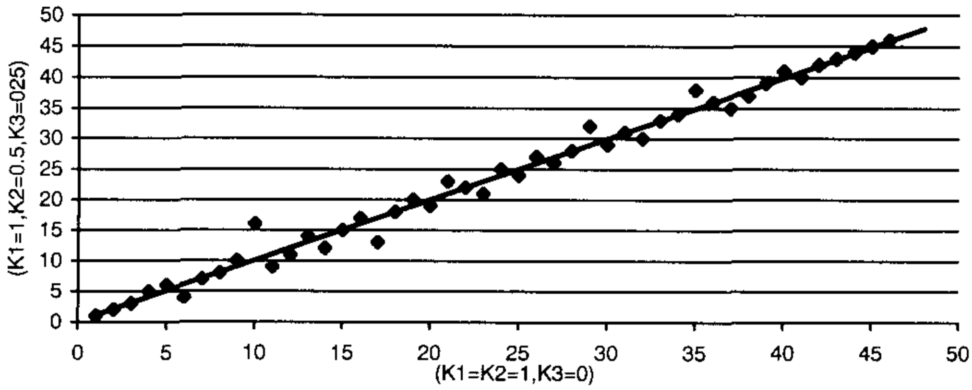

Fig.1 Rank comparing in standard topic group (Group one)

On the contrary, it was maximum (126) in $K_1=K_2=K_3=1$, where the maximum difference was 14. In this case, the noisy from the opinion of low degree of expertise strangely influenced the index (Fig.2). In another case of $K_1=1$, $K_2=0.75$, $K_3=0.5$, the noisy was also not restricted effectively (Fig.3). So, the suitable convert coefficients were $K_1=1$, $K_2=0.5$ and $K_3=0.25$(Table 2).

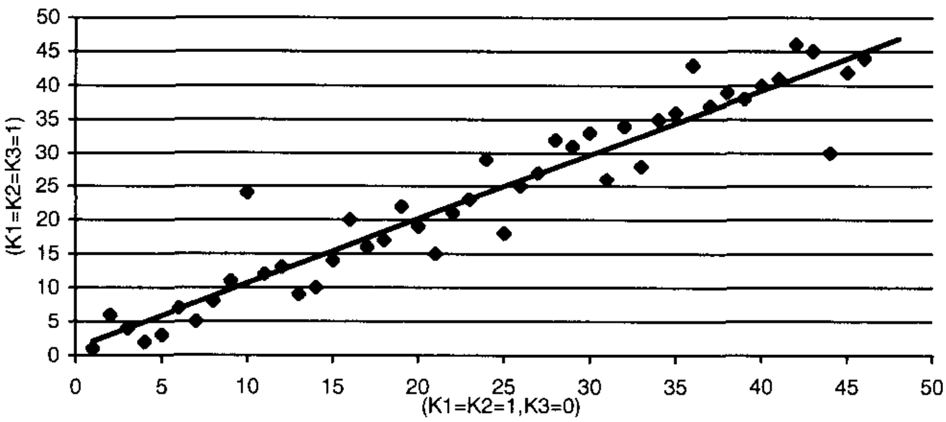

Fig.2 Rank comparing in standard topic group (Group two)

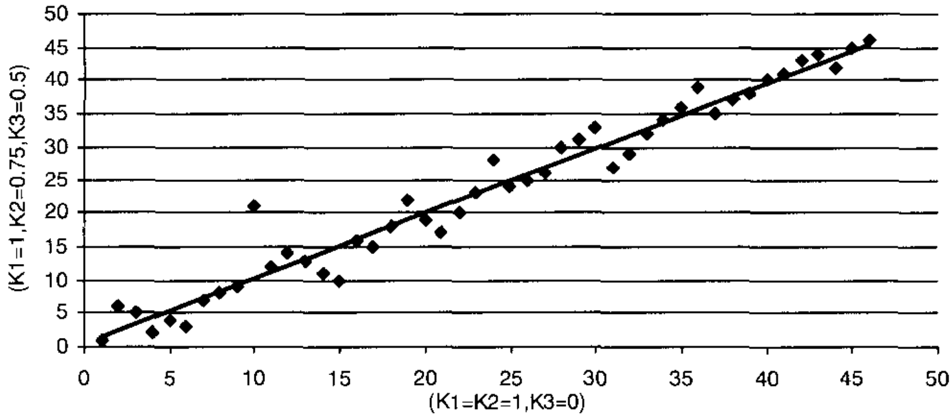

Fig.3 Rank comparing in standard topic group (Group three)

Table 2 Number of topics counted by order difference

Order Difference	(K_1=K_2=K_3 =1)	(K_1=K_2=1, K_3=0)	(K_1=1, K_2=0.75, K_3=0.5)	(K_1=1, K_2=0.75, K_3=0)	**(K_1=1, K_2=0.5, K_3=0.25)**	(K_1=1, K_2=0.5, K_3=0)
0	7	Standard	13	24	**19**	18
1	14		12	11	**16**	9
2	8		9	8	**7**	5
3	3		6	3	**2**	7
4	6		4	0	**1**	4
5	3		1	0	**0**	2
6 and above	5		1	0	**1**	1

3. Rank comparing of top 100 important topics

The importance index of top 100 important topics were calculated by formula (4) when K_1=1, K_2=0.5, K_3=0.25 (Appendix 2). The comparativeness between new rank and old rank (in Japan's seventh survey) shown in Fig.4, where the new rank directly correlated to the old rank.

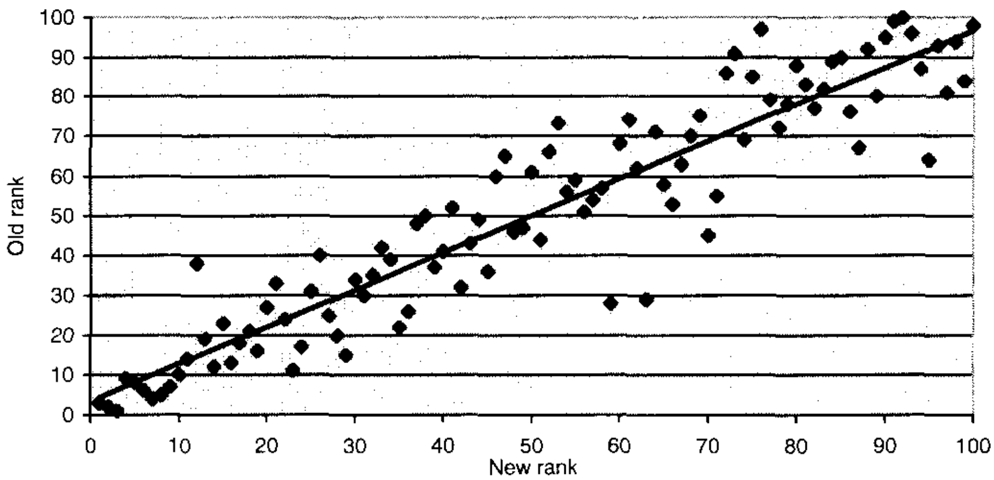

Fig. 4 The relationship between new and old rank in top 100 important topics

Nevertheless, 95% topics changed their order. About 50% topics changed their order within 5, 23% topics changed greater then 6 and less then 10, and 27% topics greater then 10 (Table 3). The top 10 topics were still in the new rank, but the third, ninth and eighth topics increased their importance and shifted to the front.

Table 3 The comparativeness of top 100 important topics between new rank and old rank

Order difference	0	1	2	3	4	5	6-10	11-15	16-20	21-25	25-30	>30
Number of the topics	5	6	14	11	5	9	23	15	6	2	1	3

Because the new method increasing the importance of high degree of expertise, or relatively decreasing the importance of medium and low degree of expertise, some topics changed their order obviously. The 28th, 29th and 64th topics in old rank changed greater then 30, down to 59th, 63th and 95th in new rank respectively. On the contrary, the 38th topic went up to 12th, where the high degree of expertise indicated the high importance, but the medium and low degree of expertise indicated the low importance.

In technological fields, the average of new important index was 88.2, slightly greater then the old (Table 4). In three fields of health and medical care, space, business and management, the difference between new and old index was greater then the others.

Table 4 The comparativeness between "Old" and "New" importance index by fields

Fields	Degree of expertise (%)			Importance Index		
(Number of topics)	High	Medium	Low	Old	New	Difference
Total (100)	**15**	**29**	**56**	**87.1**	**88.2**	**1.1**
Information and Communication (7)	14	29	57	88.1	89.5	1.4
Electronics (12)	24	33	43	86.1	87.9	1.8
Life Sciences (21)	18	35	47	88.5	89.5	1.0
Health and Medical Care (3)	19	39	42	86.7	89.5	**2.8**
Agriculture, Forestry, Fisheries and Food (9)	10	20	69	86.2	87.6	1.4
Marine Science and Earth Science (7)	11	25	63	88.7	89.9	1.2
Space (2)	21	35	45	85.5	88.3	**2.8**
Resource and Energy (5)	15	28	57	86.8	88.4	1.6
Environment (5)	10	27	62	87.4	87.8	0.4
Material and Processing (10)	12	27	61	86.1	86.6	0.5
Manufacturing (6)	11	23	67	86.2	87.3	1.1
Distribution (2)	13	34	53	85.0	86.7	1.7
Business and Management (3)	15	26	59	84.7	87.2	**2.5**
Urbanization and Construction (5)	12	26	62	86.8	87.6	0.8
Transportation (2)	7	20	73	85.5	86.1	0.6
Service (1)	2	19	80	94.0	94.8	0.8

As a reference, the important index of top 100 important topics was also calculated by six kinds of K_i (Appendix 3).

4. Grouping the priority topics

Indeed the top 100 importance topics is a simple, clear and useful result. Police making can use it to draft R&D and technology development plans as well as the budget, the enterprises draft the business plan, and the researchers understand the studying directions.

But is the rank reasonable? People always ask this question especially if the order of the topics probability related to the investment. As we discussed at the begging, this question was raised due to two reasons. First, any topic meets special socioeconomic needs, so, the priority setting should include many developing directions. Secondly, the importance was assessed by the different knowledge pool. From the statistical view, the assessing standard varies with the different expert's group, especially in different fields. This was the reason why the similar topics in Japan's seventh survey had different importance index in the relative fields.

In practice, we always need to compare the importance of the topics, such as in R&D planning or in the budget. It is relatively easy to rank the topics in the same field due to the same knowledge pool, even though the number of responses is different. But it is very difficult to compare the topics in different fields. For example, it is hardly to make the ranking when aggregating the topics from agriculture and new material or other fields.

To reduce the contradiction, we introduced the grouping way of priority topics where any topic (from all the fields) in the same group had the similar importance. To make sure the importance index in any field is comparable, the difference of assessing standard of the expert's groups must be reduced. The simple way is to use the relative importance index when aggregating all the topics.

$$I_{index}' = I_{index} * 100/(\text{Maximum of importance index in each field}) \qquad (5)$$

Where the topic with maximum index in each field is the standard (index=100), and others are relative. When aggregating all the topics, the grouping was set up by the intervals of the index, such as 0- 50, 51- 60, 61- 70, 71- 80, 81- 90 and 91- 100. The greater the values of importance index, the higher the priority groups.

The relative important index of 1065 topics in Japan's seventh survey was calculated. After ranking, new top 100 importance topics were selected based on their index. As shown in table 5, 8 topics removed from the old (Japan's seventh survey) and the same topics added from other 7 fields. The moved topics were topic 10 in information field, topic 33, 88 and 13 in life sciences, topic 33 and 40 in marine and earth science, topic 28 and 13 in resource and energy. The added topics were topic 6 from health and medical care, topic 8 and 16 from agriculture, topic 8 from space, topic 29 from environment, topic 3 from material, topic 5 from business and topic 30 from transportation.

Table 5 The comparativeness of old and new top 100 important topics by fields

Fields	Number of topics in old top 100 topics	Number of topics in new top 100 topics	Number of topics changed in top 100 topics numbers	Topics*
Total (100)			**8**	
Information and Communication	7	6	-1	*10 removed*
Electronics	12	12	0	
Life Sciences	21	18	-3	*33, 88, 13 removed*
Health and Medical Care	3	4	1	**6 added**
Agriculture, Forestry, Fisheries and Food	9	11	2	**8, 16 added**
Marine Science and Earth Science	7	5	-2	*33, 40 removed*
Space	2	3	1	**8 added**
Resource and Energy	5	3	-2	*28, 13 removed*
Environment	5	6	1	**29 added**
Material and Processing	10	11	1	**3 added**
Manufacturing	6	6	0	
Distribution	2	2	0	
Business and Management	3	4	1	**5 added**
Urbanization and Construction	5	5	0	
Transportation	2	3	1	**30 added**
Service	1	1	0	

* *The number in this column is the topic No. in each field.*

As an example, top 100 important topics can be classified into 5 groups by their index, shown in table 6. The topics in the group 1 (<98 and ≤100) will be prior to the topics in group 2 (<96 and ≤ 98), the group 2 (<96 and ≤98) prior to the group 3 (<94 and ≤ 96), and so on.

Table 6 New top 100 important topics by groups and fields

Fields	Topics				
	Group 1 (<98 and ≤100)	Group 2 (<96 and ≤98)	Group 3 (<94 and ≤96)	Group 4 (<92 and ≤94)	Group 5 (<90 and ≤92)
Total (100)	**26**	**19**	**20**	**29**	**6**
Information and Communication	19, 18		50, 79	65	12
Electronics	6, 25	10	13, 22, 36	7, 18, 29, 11, 37	1
Life Sciences	1, 38, 65	23, 37, 11, 27, 82	17, 24, 5, 14, 16, 31	9, 59, 72	87
Health and Medical Care	4	5	9	**6**	
Agriculture, Forestry, Fisheries and Food	1, 49	62, 76, 73, 75, 79	63	74, **8, 16**	
Marine Science and Earth Science	55	51		13, 63, 57	
Space	20		29	**8**	
Resource and Energy	49			53	75
Environment	21, 22, 38			39, 40	**29**
Material and Processing	99, 75, 76	62	52, 53, 86	35, 85, 33	**3**
Manufacturing	40	39, 42	41	19, 24	
Distribution	14	9			
Business and Management	25, 26	11		**5**	
Urbanization and Construction	26	4	3	1, 14	
Transportation	29		26	**30**	
Service	31				

Note: The number in the table is the topic No. in each field.

From the view of groups and fields, the topics in electronics field focused in the priority group 3 and 4, life science in group 2 and 3, agriculture in group 2, marine and earth science in group 4, material and processing in group 1, 3, 5.

The average value of relative important index was 67.4, slightly greater then the old. As shown in table 7, agriculture and business field increased their importance, and marine and earth science, resource and energy as well as services fields decreased their importance.

Table 7 The comparativeness of old and new Important index by fields

Fields	Importance		Relative importance	
	Index	Rank	Index	Rank
Total	61.2		67.4	
Life science	72.6	1	78.1	1
Electronics	66.2	2	72.8	2
Environment	65.5	3	72.8	3
Manufacturing	65.4	4	72.6	4
Agriculture	62.4	7	70.1	5
Materials and processes	62.7	6	69.6	6
Business	59.5	**10**	69.2	7
Marine and earth	63.6	*5*	67.0	8
Health and medical care	59.3	**11**	66.6	9
Information	60.5	9	65.0	10
Resource and energy	60.8	*8*	64.6	11
Urbanization	57.5	12	63.2	12
Transportation	55.1	14	62.7	13
Space	53.1	15	60.3	14
Services	55.6	*13*	59.1	15
Distribution	46.6	16	54.2	16

5. Conclusions

The degree of expertise is one of the major factors in calculating the importance index. Though introducing the convert coefficients, we attach the importance to the opinion of high degree of expertise, e.g. the higher the degree of expertise, the greater the weighted value. The convert coefficients were determined by comparing the topic rank of six kinds of K_i in the standard topic group. The result indicated the suitable convert coefficients was $K_1=1$, $K_2=0.5$, $K_3=0.25$.

If the percentage of high degree of expertise was quit low, the importance was probably incredible. In this case, we have to increase the number of high degree of expertise in priority setting, or don't include these topics.

It is very difficult to directly compare the importance of topics in different fields due to any topic meets special socioeconomic needs and the importance assessed by the different knowledge pool. Therefore, the priority setting should include many developing directions. To reduce the difference of assessing standard of the expert's groups, we introduced the relative importance index and grouping the priority topics. It is very clear what is the importance after grouping the priority topics, where the topics in the group with high importance will be prior to the other groups with relative low importance. The statistical data shown that 8 topics changed in top 100 importance topics by using the relative importance index.

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Appendix 1 Importance index by six kinds K_i in standard topic group

Field	Topic	Number of respondent	Degree of expertise (%)			(K_1=K_2 =K_3=1)		(K_1=K_2 =1, K_3=0)		(K_1=1, K_2=0.75, K_3=0.5)		(K_1=1, K_2=0.75, K_3=0)		(K_1=1, K_2=0. 5, K_3=0.25)		(K_1=1, K_2=0. 5, K_3=0)	
			high	med.	low	index	Rank	index	Rank	index	rank	index	rank	index	rank	index	Rank
Resource	49	104	24	22	54	93.8	1	95.3	**1**	94.4	1	95.7	**1**	95.2	1	96.2	1
Marine & earth	51	88	17	30	53	92.0	6	93.8	**2**	92.8	6	94.5	**2**	94.0	2	95.5	2
Information	18	196	18	35	47	92.3	4	93.5	**3**	92.9	5	94.0	**3**	93.8	3	94.7	3
Life Science	65	128	20	34	46	93.0	2	93.4	**4**	93.2	2	93.6	**4**	93.5	5	93.9	5
Information	19	189	18	33	49	92.8	3	93.3	**5**	93.0	4	93.6	**5**	93.4	6	93.9	4
Life Science	1	159	36	42	21	91.9	7	93.1	**6**	93.1	3	93.4	**6**	93.5	4	93.7	6
Life Science	38	141	15	35	50	92.3	5	93.0	**7**	92.6	7	93.3	**7**	93.1	7	93.7	7
Electronics	6	191	43	36	21	90.6	8	91.4	**8**	91.3	8	91.9	**8**	92.2	8	92.6	8
Life Science	23	140	19	41	39	89.4	11	90.6	**9**	90.5	9	90.7	**12**	90.7	10	90.9	19
Resource	53	171	23	23	54	87.5	24	90.5	**10**	88.7	21	91.3	**9**	90.3	16	92.3	9
Life Science	24	142	23	36	41	89.3	12	90.4	**11**	89.9	12	90.9	**10**	90.8	9	91.6	11
Life Science	27	115	13	36	51	89.3	13	90.4	**12**	89.8	14	90.9	**11**	90.6	11	91.7	10
Environment	38	192	13	31	56	89.5	9	90.4	**13**	89.9	13	90.7	**13**	90.4	14	91.2	13
Life Science	11	160	27	34	39	89.5	10	90.3	**14**	90.0	11	90.7	**14**	90.6	12	91.1	14
Life Science	37	140	14	34	51	89.1	14	90.3	**15**	90.1	10	90.4	**17**	90.3	15	90.5	20
Information	50	152	20	30	49	88.0	20	90.0	**16**	89.4	16	90.4	**16**	90.2	17	91.0	15
Space	20	100	24	35	41	88.7	16	90.0	**17**	89.5	15	90.5	**15**	90.4	13	91.3	12
Life Science	16	145	20	34	46	88.3	17	89.6	**18**	89.0	18	90.2	**18**	89.9	18	90.9	18
Life Science	14	145	24	31	45	87.8	22	89.5	**19**	88.7	22	90.1	**19**	89.8	20	91.0	16
Life Science	17	146	20	36	44	88.1	19	89.5	**20**	88.9	19	90.1	**20**	89.9	19	91.0	17
Health	4	126	23	44	33	88.8	15	89.2	**21**	89.1	17	89.5	**23**	89.6	23	89.9	24
Life Science	5	154	28	38	34	88.0	21	89.1	**22**	88.7	20	89.6	**21**	89.7	22	90.4	22
Electronics	10	180	39	34	27	87.6	23	88.9	**23**	88.6	23	89.6	**22**	89.8	21	90.4	21
Business	25	106	18	30	52	85.8	29	88.1	**24**	86.8	28	88.9	**24**	88.3	25	90.1	23
Life Science	9	148	26	43	32	88.3	18	88.0	**25**	87.9	24	88.4	**25**	88.5	24	88.9	28
Health	5	124	20	42	38	87.0	25	87.6	**26**	87.4	25	87.9	**29**	88.0	27	88.4	30
Information	12	206	21	40	39	86.3	27	87.6	**27**	87.1	26	88.2	**27**	88.2	26	89.2	27
Marine & earth	27	126	10	35	55	85.5	32	87.5	**28**	86.4	30	88.3	**26**	87.8	28	89.7	25
Materials	53	151	17	29	54	85.7	31	87.2	**29**	86.3	31	87.7	**30**	87.3	32	88.5	29
Life Science	87	138	10	36	54	85.3	33	87.2	**30**	86.2	33	88.0	**28**	87.6	29	89.5	26
Life Science	72	133	17	39	44	86.5	26	87.1	**31**	86.9	27	87.5	**32**	87.4	31	87.9	33
Electronics	22	162	20	38	41	85.0	34	87.0	**32**	86.5	29	87.5	**31**	87.4	30	88.3	31
Electronics	13	161	17	36	47	86.0	28	86.6	**33**	86.3	32	86.9	**33**	86.8	33	87.3	35
Electronics	7	191	42	36	22	85.0	35	85.9	**34**	85.8	34	86.4	**36**	86.6	34	87.1	37
Materials	86	107	14	30	56	84.6	36	85.9	**35**	85.2	36	86.3	**38**	85.9	38	87.0	39
Space	29	95	17	34	49	83.7	43	85.8	**36**	84.8	39	86.7	**34**	86.2	36	88.0	32
Life Science	13	141	21	39	40	84.3	37	85.8	**37**	85.2	35	86.6	**35**	86.5	35	87.7	34

Field	Topic	Number of respondent	Degree of expertise (%)			$(K_1=K_2=K_3=1)$		$(K_1=K_2=1, K_3=0)$		$(K_1=1, K_2=0.75, K_3=0.5)$		$(K_1=1, K_2=0.75, K_3=0)$		$(K_1=1, K_2=0.5, K_3=0.25)$		$(K_1=1, K_2=0.5, K_3=0)$	
			high	med.	low	index	Rank	index	Rank	index	rank	index	rank	index	rank	index	rank
Urbanization	14	166	27	31	42	84.0	39	85.7	**38**	85.0	37	86.4	**37**	86.1	37	87.3	36
Health	9	115	15	30	55	84.3	38	85.7	**39**	84.9	38	86.2	**39**	85.8	39	87.0	38
Distribution	9	102	16	41	43	84.0	40	84.9	**40**	84.6	40	85.4	**40**	85.4	41	86.2	40
Electronics	11	193	28	45	27	83.8	41	84.6	**41**	84.5	41	85.1	**41**	85.4	40	85.9	41
Environment	40	209	10	33	56	83.0	46	84.6	**42**	84.2	43	84.9	**42**	84.6	42	85.3	42
Electronics	1	192	17	36	47	83.3	45	84.2	**43**	83.7	44	84.6	**43**	84.4	43	85.2	43
Electronics	36	151	21	26	54	85.8	30	83.7	**44**	84.4	42	83.4	**45**	83.7	44	82.9	45
Environment	39	198	19	25	56	83.8	42	83.5	**45**	83.7	45	83.5	**44**	83.5	45	83.4	44
Electronics	37	134	25	24	51	83.5	44	83.0	**46**	83.3	46	82.8	**46**	83.0	46	82.6	46

All respondents if K_3 not equal to 0, and only respondents of high & medium degree of expertise if $K_3=0$.

Appendix 2: Rank comparing of top 100 importance topics

Field		Topic	Old $K_1=K_2=K_3=1$		New $K_1=1$, $K_2=0.5$, $K_3=0.25$	
			Index	Rank	Index	Rank
Resource	49	Practical use of technology for the safe disposal of highly radioactive solid waste.	94	3	95.2	**1**
Services	31	Major advances in technology for disposing of disused manufactured products, leading to the emergence of commercial services capable of reducing the final disposal volume to one-tenth the current level	94	2	94.8	**2**
Marine & earth	55	Development of technology capable of forecasting the occurrence of major earthquakes (magnitude 7 or above) several days in advance	95	1	94.3	**3**
Marine & earth	51	Establishment of a method for evaluating the safety of the underground disposal of high-level radioactive wastes.	92	9	94.0	**4**
Information	18	Realization of an environment in which the unlimited utilization of high-capacity networks (150Mbps) for around 2,000 yen/month or less is possible.	92	8	93.8	**5**
Life Science	1	Development of methods for surmising new functions of proteins from DNA base sequence data.	93	6	93.5	**6**
Life Science	65	Identification and classification by the molecular etiology of the genes related to diabetes, hypertension, and arteriosclerosis, which are typical lifestyle diseases that exhibit multiple-factor hereditary traits.	93	4	93.5	**7**
Information	19	Widespread use of highly reliable network systems capable of protecting the privacy and secrecy of individuals and groups from the intrusion of ill-intentioned network intruders.	93	5	93.4	**8**
Life Science	38	Practical use of effective means to prevent metastasis of cancer.	93	7	93.1	**9**
Electronics	6	Practical use of technology enabling the mass production of LSI with minimum pattern dimensions of 10nm	91	10	92.2	**10**
Manufacturing	40	Widespread use of a design - manufacturing - collection - recycling system in which manufacturers are obligated by law to collect and dispose of disused products, and at least 90% of used material is recycled.	90	14	92.1	**11**
Agriculture	49	Practical use of rational resources management technology once elucidation of the reproduction processes of major fishery resources makes it possible to predict long-term (10-20 years) changes.	88	38	91.5	**12**
Materials	99	Practical use of systems for the genetic diagnosis and treatment of cancer and incurable diseases based on genome analysis.	90	19	91.3	**13**
Urbanization	26	Practical use of technology for disposing of high-level radioactive waste.	91	12	91.0	**14**
Life Science	24	Complete understanding of the factors contributing to stem cell proliferation, and widespread use of the practice of proliferating stem cells, as necessary, *in vitro* and using them for medical treatment.	89	23	90.8	**15**
Life Science	23	Widespread use of medical treatment that leads dysdifferentiating carcinogenic cells into normal state by controlling the signal transduction in carcinogenesis of cells	91	13	90.7	**16**

Field		Topic	Old $K_1=K_2=K_3=1$		New $K_1=1$, $K_2=0.5$, $K_3=0.25$	
			Index	Rank	Index	Rank
Life Science	27	Practical use of an effective drug against multiple-drug-resistant bacteria, including vancomycin-resistant bacteria.	90	18	90.6	**17**
Environment	22	Practical use of technology capable of reducing particulate matter emissions from diesel vehicles to 10% of current levels (fiscal 1999 standard value for vehicles weighing more then 2.5t is 0.25 g/kWh (average value))	90	21	90.6	**18**
Life Science	11	It becomes possible to determine the entire base sequences of an individual including genetic structure and SNP (Single nucletide polymorphism) promptly and cheaply, leading to widespread use of such methods for diagnosis and tailor-made treatment.	90	16	90.6	**19**
Marine & earth	13	Elucidation of the mechanisms of replacement of dominant fish species such as horse mackerel, sardine, saury and mackerel.	89	27	90.5	**20**
Space	20	The cost of rocket thrusted space transportation will be reduced to less than 1/10 current levels.	88	33	90.4	**21**
Environment	38	Large reduction of the amount of buried industrial waste as a result of advances in the reorganization and integration of industrial technology aimed at reducing waste emission to zero.	89	24	90.4	**22**
Life Science	37	Widespread use of drugs capable of preventing the occurrence of certain types of cancer.	91	11	90.3	**23**
Environment	21	Widespread use in virtually all types of automobiles of technique capable of meeting an emission control standard that specifies a nitrogen oxide emission limit of 0.1 to 0.2 g/km. (Current emissions from heavy diesel motorcars are about 4 to 5 g/km, and the 1978 standard value for gasoline passenger cars is 0.25 g/km.)	90	17	90.3	**24**
Agriculture	1	Determination of the whole DNA sequence of crops (e.g. rice) to isolate useful genes.	89	31	90.3	**25**
Resource	53	Widespread use of fuel cells as a highly efficient, environmentally safe, and portable power source (e.g. for electric vehicles)	88	40	90.3	**26**
Information	50	Advance in software inspection and verification technology, enabling error-free, large-scale software to be developed in a short period of time.	89	25	90.2	**27**
Electronics	25	Widespread use of portable multimedia wireless terminal operating at about 100 Mbps, which can be used throughout the world.	90	20	90.1	**28**
Life Science	82	Development of technologies which dramatically improve photosynthetic functions in order to increase food production and preserve the environment.	90	15	90.0	**29**
Life Science	16	Development of technology to regenerate targeted organs from differentiated animal cells.	88	34	89.9	**30**
Life Science	17	It becomes possible to differentiate separated stem cells into any organ *in vitro*, leading to clinical application of such techniques.	89	30	89.9	**31**
Life Science	14	Elucidation of the environment factors and regulatory mechanisms of immune response which triggers allergies such as hay fever and atopy, enabling complete control over immediate type hypersensitivity diseases.	88	35	89.8	**32**

Field		Topic	Old $K_1=K_2=K_3=1$		New $K_1=1$, $K_2=0.5$, $K_3=0.25$	
			Index	Rank	Index	Rank
Electronics	10	Practical use of non-volatile, rewritable random access semiconductor memories with more than 100 Gbits capacity.	88	42	89.8	**33**
Life Science	5	Development of high-speed genome analysis technology, and determination of the entire genome sequences of at least 50 important animal and plant species.	88	39	89.7	**34**
Marine & earth	63	Formation of global consensus regarding international regulations on the emission of carbon dioxide and other greenhouse gases that cause global warming, including reductions in developing countries.	89	22	89.7	**35**
Health	4	Elucidation of carcinogenic mutation mechanisms.	89	26	89.6	**36**
Materials	62	Development of superconductors with a transition point at room temperature or higher.	87	48	89.1	**37**
Agriculture	62	Examination of the safety of genetically modified farm products from both food and environmental perspectives, and the development of an evaluation method that can gain the understanding of consumers.	87	50	88.8	**38**
Life Science	31	Production of biodegradable plastics, such as bio-plastics using microorganisms and plant, accounts for more than half of the total volume of worldwide plastic production.	88	37	88.7	**39**
Information	79	Practical use of integrated building management systems and home security systems, which are linked to an earthquake detection system, and take advantage of time delay to the arrival of seismic waves from a non-direct-hit earthquake to initiate the necessary safety measures to protect human life.	88	41	88.7	**40**
Manufacturing	42	Widespread use of a "production-destruction" manufacturing system in which a production system of "design → production → use → disuse" is combined with a resources recycling system of "collection → dismantling and sorting → reuse → production".	87	52	88.6	**41**
Marine & earth	57	Realization of time-series observation of the condition of magma inside volcanoes.	88	32	88.5	**42**
Transportation	29	Widespread use of technology to reduce the harmful components of exhaust gas from large trucks to 1/10 of present levels, such as diesel exhaust catalysts, particulate traps, lean-burn NOx catalysts and high precision combustion technology.	88	43	88.5	**43**
Life Science	9	Establishment of technologies for predicting bioactivity and functional domain of protein from their higher-order structures.	87	49	88.5	**44**
Urbanization	4	Practical use in Japan of a mid-term (5 ~ 10 years in advance) prediction technique for large-scale (Magnitude 8 or larger) earthquakes based on analyses of the crustal strain distribution and past earthquake records.	88	36	88.4	**45**
Business	25	New industries take over from the data communication industry to play a role of driving force in the next generation.	86	60	88.3	**46**
Information	12	Widespread use of systems which facilitate multimedia communication from anywhere in the word using pocketbook-size portable terminals.	85	65	88.2	**47**

Field		Topic	Old $K_1=K_2=K_3=1$		New $K_1=1$, $K_2=0.5$, $K_3=0.25$	
			Index	Rank	Index	Rank
Life Science	59	It becomes possible to prevent the progress of Alzheimer's disease.	87	46	88.1	**48**
Manufacturing	39	Widespread use of low entropy-generating eco-factories, which give due consideration to the impact on local ecosystems throughout product life cycles, from manufacture to disposal.	87	47	88.1	**49**
Distribution	14	Widespread use among at least 80% of industries of a system in which used or waste products are recycled safely and efficiently on an industry-wide basis rather than on a company or corporate group basis.	86	61	88.0	**50**
Health	5	Elucidation of cancer metastasis mechanisms.	87	44	88.0	**51**
Marine & earth	27	Widespread use of technologies for the comprehensive use and conservation of entire bays with high utilization densities, such as Tokyo Bay, Osaka Bay, etc.	85	66	87.8	**52**
Life Science	87	Formation of consensus among the research community on guidelines on ethics-based research controls in the life science field in Japan.	85	73	87.6	**53**
Electronics	22	Development of logic LSIs with 10 GOPS (giga-operations per second) performance and power consumption of 10 milliwatts or less.	86	56	87.4	**54**
Agriculture	73	Practical use of technological structures and systems for the proper use of forests while preserving the forests and their functions (maintenance of biodiversity, environmental purification, and provision of scenery and comfort).	86	59	87.4	**55**
Life Science	72	Practical use of cancer treatment methods capable of distinguishing cancerous cells from normal cells, and targeting those cancerous cells.	87	51	87.4	**56**
Agriculture	79	Integration of food safety administration, and establishment of forums for extensive discussions on food safety and effective use of feedback for administration.	86	54	87.4	**57**
Information	65	Widespread use of online seal-free (signature-free) document preparation services for various official documents such as contracts, which are provided via a network based on security technology capable of achieving both privacy protection and verification.	86	57	87.4	**58**
Materials	76	Practical use of large-area amorphous silicon solar cells with a conversion efficiency of more than 20%.	89	28	87.3	**59**
Materials	53	Practical use of hydrogen production processes for water decomposition by sunlight.	85	68	87.3	**60**
Business	26	Industry clusters (structure in which each industry utilizes the waste products of other industries in the waste process) are established, and industries are obligated to place reusable industrial waste on that recycling route.	85	74	87.0	**61**
Manufacturing	41	Widespread use of zero emission factories as a result of advances in the development of carbon dioxide collection technology.	86	62	87.0	**62**
Materials	75	Practical use of multi-layer solar cell with a conversion efficiency of more than 50%.	89	29	86.9	**63**

Field		Topic	Old $K_1=K_2=K_3=1$		New $K_1=1$, $K_2=0.5$, $K_3=0.25$	
			Index	Rank	Index	Rank
Electronics	18	Practical use of card-size wireless communication instrument capable of changing specification, such as center frequencies, band width, modulation method, and error correction method, by software operation.	85	71	86.9	**64**
Electronics	13	Practical use of TOPS (tera-operation per second) level microprocessors.	86	58	86.8	**65**
Urbanization	3	Development of a nationwide network for detecting earthquakes, and widespread use in Japan of a disaster prevention system that gives advance warning of earthquakes likely to occur at a distance of 50km or more.	87	53	86.8	**66**
Resource	75	Establishment of waste sorting and collection systems, leading to widespread use of recycling systems that produce, distribute and consume recycled materials and goods based on new economic criteria and standard.	86	63	86.7	**67**
Electronics	7	Practical use of VLSI with more than 256 Gbits of memory per chip.	85	70	86.6	**68**
Life Science	13	Identification of most immunologically functional molecules responsible for organ transplant rejection, enabling organ transplantation free of side effects.	84	75	86.5	**69**
Agriculture	76	Elucidation of the mechanism by which the toxicity of endocrine-disrupting chemicals is manifest and its effect on reproductive functions, behavior, brain functions, immune functions, etc., and the establishment of safe limits for humans and livestock.	87	45	86.5	**70**
Agriculture	75	Development of factories that purify river water by fixing bacteria that breakdown dioxin and other endocrine disrupters in carries such as porous charcoal.	86	55	86.5	**71**
Agriculture	63	Development of food capable of supporting a healthy aging society from a nutritional perspective by preventing a decline in anti oxidation, brain and chewing functions.	84	86	86.4	**72**
Business	11	Network crime is reduced to about half current levels as a result of advances in information technology.	83	91	86.3	**73**
Electronics	29	Practical use of technology that can completely automatically design high performance LSIs with several hundred kilo gates or more when given the required system-level specifications written in a high-level language such as C.	85	69	86.3	**74**
Life Science	88	Guidelines for life science research in Japan's research community form the basis for enactment of related laws and regulations, and are shared by the entire Japanese society.	84	85	86.3	**75**
Space	29	Widespread use of gigabit-class global satellite communication functions.	83	97	86.2	**76**
Urbanization	14	Widespread use in Japan of technology that accurately simulates the behaviors of structures or the ground at time of a string earthquake.	84	79	86.1	**77**
Materials	86	Development of three-dimensional cumulative processing technology of nanometer scale.	85	72	85.9	**78**
Health	9	Elucidation of arteriosclerosis contraction mechanisms.	84	78	85.8	**79**

Field		Topic	Old $K_1=K_2=K_3=1$		New $K_1=1$, $K_2=0.5$, $K_3=0.25$	
			Index	Rank	Index	Rank
Urbanization	1	Widespread use in Japan of warning, forecasting, evacuation assistance and crowd control systems that dramatically reduce human loss in the event of a natural disaster involving rivers, roads, etc. based on localized weather forecasts.	84	88	85.8	**80**
Manufacturing	19	Development of semiconductor micro-processing and measuring technology of 1nm resolution for manufacturing 0.01 micron-rule LSI.	84	83	85.7	**81**
Electronics	11	Practical use of LSIs operating at clocking frequencies of more than 50 GHz.	84	77	85.4	**82**
Distribution	9	Widespread use by at least 80% of companies in the food sector of zero-waste or 100% recyclable product development within the distribution process, including packaging.	84	82	85.4	**83**
Materials	35	Widespread use of recycling systems for general-purpose plastics, allowing recycled goods to account for at least 30% of total production.	84	89	85.3	**84**
Resource	13	Practical use of rational methods of collecting and recycling useful substances in urban garbage based on an LCA (lift cycle assessment) perspective.	83	90	85.1	**85**
Information	10	The number of recycled parts in new personal computers, including displays, exceeds 90% of all component parts.	84	76	85.0	**86**
Materials	52	Practical use of carbon dioxide fixation technology necessary for protection the global environment.	85	67	84.9	**87**
Resource	28	Practical use of methane hydrate mining technology.	83	92	84.8	**88**
Environment	40	Introduction of an environmental tax in Japan with the aim of preserving the global environment.	84	80	84.6	**89**
Electronics	1	Practical use of single atom/molecule manipulation techniques as methods for device fabrication and gene manipulation.	83	95	84.4	**90**
Marine & earth	40	Nationwide installation of bore-hole-type observation equipment integrating various types of gauges (e.g., seismometers, tiltmeters, and strain-gauges) for use in earthquake forecasting.	83	99	84.4	**91**
Materials	33	Widespread use of polymer synthesizing processes that use renewable resources instead of conventional petrochemical processes.	83	100	84.3	**92**
Agriculture	74	Widespread use of environmental repair technology capable of clearing the pollution of closed water areas, such as Kasumigaura, to prewar levels using organism and ecosystem functions.	83	96	84.2	**93**
Materials	85	Practical use pf memory chips with a capacity of 1 terabit.	84	87	83.9	**94**
Electronics	36	Widespread use of 10 Gbps optical subscriber systems in homes.	86	64	83.7	**95**
Transportation	26	Widespread use of electric cars equipped with fuel cells.	83	93	83.6	**96**
Environment	39	Reduction of global carbon dioxide emissions to 20% below the 1990 level.	84	81	83.5	**97**
Life Science	33	Practical use of technology for the immediate biological fixation of highly concentrated carbon dioxide emitted from thermal power stations.	83	94	83.4	**98**

Field		Topic	Old $K_1=K_2=K_3=1$		New $K_1=1$, $K_2=0.5$, $K_3=0.25$	
			Index	Rank	Index	Rank
Electronics	37	Practical use of optical communication systems capable of transmitting signals through multiplexed 1,000 channels at 100 Gbps over a single optical fiber.	84	84	83.0	**99**
Manufacturing	24	Widespread use of non-fossil energy sources (wind, geothermal, PV/solar heat, and waste heat) in all areas of manufacturing.	83	98	82.1	**100**

$I_{index}=I_H*W_H+ I_H*W_H+ I_H*W_H$

Where:

$I_H =(100*N_{11} +50*N_{12}+25*N_{13})/ T_H$ $\quad$ $W_H= T_H/T_{all}$

$I_M =(100*N_{21} +50*N_{22}+25*N_{23})/ T_M$ $\quad$ $W_M=0.5* T_M/T_{all}$

$I_L =(100*N_{31} +50*N_{32}+25*N_{33})/ T_L$ $\quad$ $W_L=0.25* T_L/T_{all}$

$T_{all}= T_H +0.5 T_M+0.25T_L$ (the number of converted respondents)

Appendix 3: Importance index and rank of top 100 important topics by six kinds of K_i

Field	Topic	Number of respondent	Degree of expertise (%)			($K_1=K_2=K_3=1$)		($K_1=K_2=1$, $K_3=0$)		($K_1=1$, $K_2=0.75$, $K_3=0.5$)		($K_1=1$, $K_2=0.75$, $K_3=0$)		($K_1=1$, $K_2=0.5$, $K_3=0.25$)		($K_1=1$, $K_2=0.5$, $K_3=0$)	
			high	med.	low	index	Rank	index	Rank	index	rank	index	rank	index	rank	index	rank
Resource	49	104	24	22	54	*93.8*	*3*	95.3	1	94.4	3	95.7	1	95.2	**1**	96.2	1
Services	31	54	2	19	80	*95.5*	*2*	95.0	2	94.6	1	95.1	2	94.8	**2**	95.4	3
Marine & earth	55	94	11	19	70	*94.8*	*1*	94.1	3	94.6	2	93.9	5	94.3	**3**	93.7	11
Marine & earth	51	88	17	30	53	*92.0*	*9*	93.8	4	92.8	8	94.5	3	94.0	**4**	95.5	2
Information	18	196	18	35	47	*92.3*	*8*	93.5	5	92.9	7	94.0	4	93.8	**5**	94.7	4
Life Science	1	159	36	42	21	*91.9*	*6*	93.1	8	93.1	5	93.4	9	93.5	**6**	93.7	9
Life Science	65	128	20	34	46	*93.0*	*4*	93.4	6	93.2	4	93.6	7	93.5	**7**	93.9	8
Information	19	189	18	33	49	*92.8*	*5*	93.3	7	93.0	6	93.6	8	93.4	**8**	93.9	7
Life Science	38	141	15	35	50	*92.3*	*7*	93.0	9	92.6	9	93.3	10	93.1	**9**	93.7	10
Electronics	6	191	43	36	21	*90.6*	*10*	91.4	13	91.3	10	91.9	13	92.2	**10**	92.6	13
Manufacturing	40	142	11	26	63	*90.3*	*14*	92.3	11	91.0	11	93.0	11	92.1	**11**	94.1	6
Agriculture	49	93	24	14	62	*88.0*	*38*	92.9	10	89.6	25	93.7	6	91.5	**12**	94.7	5
Materials	99	101	8	25	67	*89.8*	*19*	91.6	12	90.3	14	92.2	12	91.3	**13**	93.2	12
Urbanization	26	71	10	15	75	*90.5*	*12*	91.3	14	90.7	12	91.5	15	91.0	**14**	91.8	18
Life Science	24	142	23	36	41	*89.3*	*23*	90.4	21	89.9	19	90.9	19	90.8	**15**	91.6	21
Life Science	23	140	19	41	39	*89.4*	*13*	90.6	17	90.5	13	90.7	21	90.7	**16**	90.9	33
Life Science	27	115	13	36	51	*89.3*	*18*	90.4	22	89.8	21	90.9	20	90.6	**17**	91.7	19
Environment	22	151	5	23	73	*90.5*	*21*	91.0	16	90.0	17	91.5	16	90.6	**18**	92.4	15
Life Science	11	160	27	34	39	*89.5*	*16*	90.3	24	90.0	18	90.7	24	90.6	**19**	91.1	26
Marine & earth	13	75	16	19	65	*88.8*	*27*	91.1	15	89.5	26	91.7	14	90.5	**20**	92.5	14
Space	20	100	24	35	41	*88.7*	*33*	90.0	28	89.5	27	90.5	25	90.4	**21**	91.3	22
Environment	38	192	13	31	56	*89.5*	*24*	90.4	23	89.9	20	90.7	23	90.4	**22**	91.2	24
Life Science	37	140	14	34	51	*89.1*	*11*	90.3	25	90.1	15	90.4	29	90.3	**23**	90.5	37
Environment	21	155	5	25	70	*89.3*	*17*	90.6	18	89.6	24	91.1	18	90.3	**24**	91.9	17
Agriculture	1	218	13	23	64	*89.5*	*31*	90.4	20	89.8	22	90.7	22	90.3	**25**	91.1	27
Resource	53	171	23	23	54	*87.5*	*40*	90.5	19	88.7	34	91.3	17	90.3	**26**	92.3	16
Information	50	152	20	30	49	*88.0*	*25*	90.0	27	89.4	28	90.4	27	90.2	**27**	91.0	28
Electronics	25	171	8	34	58	*89.5*	*20*	90.0	26	89.7	23	90.3	30	90.1	**28**	90.7	36
Life Science	82	79	13	25	62	*90.0*	*15*	90.0	29	90.0	16	90.0	35	90.0	**29**	90.0	42
Life Science	16	145	20	34	46	*88.3*	*34*	89.6	32	89.0	31	90.2	31	89.9	**30**	90.9	32
Life Science	17	146	20	36	44	*88.1*	*30*	89.5	34	88.9	32	90.1	33	89.9	**31**	91.0	31
Life Science	14	145	24	31	45	*87.8*	*35*	89.5	33	88.7	35	90.1	32	89.8	**32**	91.0	29
Electronics	10	180	39	34	27	*87.6*	*42*	88.9	39	88.6	37	89.6	38	89.8	**33**	90.4	38
Life Science	5	154	28	38	34	*88.0*	*39*	89.1	38	88.7	33	89.6	37	89.7	**34**	90.4	39
Marine & earth	63	144	4	24	72	*88.8*	*22*	90.0	30	89.1	30	90.4	28	89.7	**35**	91.2	23
Health	4	126	23	44	33	*88.6*	*26*	89.2	36	89.1	29	89.5	39	89.6	**36**	89.9	43

Field	Topic	Number of respondent	Degree of expertise (%)			($K_1=K_2=K_3=1$)		($K_1=K_2=1$, $K_3=0$)		($K_1=1$, $K_2=0.75$, $K_3=0.5$)		($K_1=1$, $K_2=0.75$, $K_3=0$)		($K_1=1$, $K_2=0.5$, $K_3=0.25$)		($K_1=1$, $K_2=0.5$, $K_3=0$)	
			high	med.	low	index	Rank	index	Rank	index	rank	index	rank	index	rank	index	rank
Materials	62	115	15	26	59	86.8	48	89.2	35	87.7	46	90.0	34	89.1	37	91.2	25
Agriculture	62	200	13	23	64	86.8	50	89.2	37	87.6	47	89.9	36	88.8	38	91.0	30
Life Science	31	102	8	32	60	87.8	37	88.7	41	88.2	40	89.1	43	88.7	39	89.7	46
Information	79	110	5	17	77	86.5	41	89.7	31	87.9	43	90.4	26	88.7	40	91.6	20
Manufacturing	42	147	13	29	58	86.3	52	88.6	42	87.2	50	89.4	40	88.6	41	90.7	35
Marine & earth	57	79	10	28	62	88.8	32	88.5	43	88.7	36	88.4	49	88.5	42	88.3	64
Transportation	29	122	9	18	73	88.0	43	88.8	40	88.2	39	89.0	44	88.5	43	89.4	50
Life Science	9	148	26	43	32	88.3	49	88.0	51	87.9	44	88.4	50	88.5	44	88.9	56
Urbanization	4	155	5	30	65	87.8	36	88.5	45	88.0	41	88.7	47	88.4	45	89.2	53
Business	25	106	18	30	52	85.8	60	88.1	50	86.8	54	88.9	45	88.3	46	90.1	40
Information	12	206	21	40	39	86.3	65	87.6	54	87.1	51	88.2	54	88.2	47	89.2	52
Life Science	59	120	13	28	60	87.9	46	88.1	47	87.5	48	88.5	48	88.1	48	89.1	54
Manufacturing	39	121	9	27	64	87.5	47	88.1	49	87.7	45	88.3	51	88.1	49	88.7	59
Distribution	14	98	10	27	63	85.5	61	88.2	46	86.5	61	89.2	41	88.0	50	90.7	34
Health	5	124	20	42	38	87.0	44	87.6	53	87.4	49	87.9	58	88.0	51	88.4	62
Marine & earth	27	126	10	35	55	85.5	66	87.5	56	86.4	62	88.3	52	87.8	52	89.7	45
Life Science	87	138	10	36	54	85.3	73	87.2	59	86.2	65	88.0	56	87.6	53	89.5	49
Electronics	22	162	20	38	41	85.0	56	87.0	62	86.5	60	87.5	63	87.4	54	88.3	65
Agriculture	73	142	7	15	77	85.3	59	88.5	44	86.6	56	89.1	42	87.4	55	90.1	41
Life Science	72	133	17	39	44	86.5	51	87.1	60	86.9	52	87.5	64	87.4	56	87.9	68
Agriculture	79	194	7	21	72	86.5	54	87.8	52	86.8	53	88.2	55	87.4	57	88.8	58
Information	65	169	14	25	62	87.0	57	87.5	55	86.6	55	87.9	59	87.4	58	88.6	60
Materials	76	114	11	25	65	90.0	28	87.0	61	88.4	38	86.3	78	87.3	59	85.2	89
Materials	53	151	17	29	54	85.7	68	87.2	58	86.3	63	87.7	61	87.3	60	88.5	61
Business	26	103	13	24	63	84.5	74	87.4	57	85.5	71	88.3	53	87.0	61	89.7	47
Manufacturing	41	110	8	15	77	85.5	62	88.1	48	86.1	66	88.8	46	87.0	62	89.8	44
Materials	75	110	10	30	60	88.8	29	86.9	64	88.0	42	86.2	81	86.9	63	85.0	91
Electronics	18	141	11	30	59	84.8	71	86.8	66	85.6	70	87.6	62	86.9	64	88.9	57
Electronics	13	161	17	36	47	86.0	58	86.6	69	86.3	64	86.9	67	86.8	65	87.3	70
Urbanization	3	167	10	27	63	86.5	53	86.8	68	86.6	58	86.9	68	86.8	66	87.0	75
Resource	75	162	10	28	62	85.3	63	86.8	67	85.8	67	87.4	65	86.7	67	88.3	63
Electronics	7	191	42	36	22	85.0	70	85.9	76	85.8	69	86.4	74	86.6	68	87.1	74
Life Science	13	141	21	39	40	84.3	75	85.8	79	85.2	73	86.6	72	86.5	69	87.7	69
Agriculture	76	157	4	19	76	85.8	45	86.5	70	86.6	59	86.4	73	86.5	70	86.3	82
Agriculture	75	162	5	19	77	87.6	55	86.4	71	86.6	57	86.3	79	86.5	71	86.1	85
Agriculture	63	129	12	24	64	83.8	86	86.8	65	84.8	79	87.8	60	86.4	72	89.3	51
Business	11	111	14	23	63	83.3	91	86.9	63	84.5	84	88.0	57	86.3	73	89.6	48
Electronics	29	136	16	24	60	85.5	69	86.4	72	85.8	68	86.6	71	86.3	74	87.0	78
Life Science	88	135	10	30	60	83.5	85	86.3	73	84.6	82	87.3	66	86.3	75	89.0	55

Field	Topic	Number of respondent	Degree of expertise (%)			(K_1=K_2 =K_3=1)		(K_1=K_2 =1, K_3=0)		(K_1=1, K_2=0.75, K_3=0.5)		(K_1=1, K_2=0.75, K_3=0)		(K_1=1, K_2=0. 5, K_3=0.25)		(K_1=1, K_2=0. 5, K_3=0)	
			high	med.	low	index	Rank	index	Rank	index	rank	index	rank	index	rank	index	rank
Space	29	95	17	34	49	*83.7*	*97*	85.8	78	84.8	80	86.7	70	86.2	**76**	88.0	66
Urbanization	14	166	27	31	42	*84.0*	*79*	85.7	80	85.0	75	86.4	75	86.1	**77**	87.3	71
Materials	86	107	14	30	56	*84.6*	*72*	85.9	77	85.2	74	86.3	77	85.9	**78**	87.0	77
Health	9	115	15	30	55	*84.3*	*78*	85.7	81	84.9	76	86.2	80	85.8	**79**	87.0	76
Urbanization	1	183	10	25	66	*84.8*	*88*	86.1	74	84.7	81	86.8	69	85.8	**80**	88.0	67
Manufacturing	19	93	16	24	60	*84.3*	*83*	85.9	75	84.9	77	86.4	76	85.7	**81**	87.1	72
Electronics	11	193	28	45	27	*83.8*	*77*	84.6	90	84.5	85	85.1	89	85.4	**82**	85.9	86
Distribution	9	102	16	41	43	*84.0*	*82*	84.9	86	84.6	83	85.4	86	85.4	**83**	86.2	84
Materials	35	162	12	30	58	*83.8*	*89*	85.3	82	84.4	86	85.9	82	85.3	**84**	86.8	79
Resource	13	163	10	31	59	*83.0*	*90*	85.0	84	83.8	90	85.8	83	85.1	**85**	87.1	73
Information	10	155	4	20	76	*84.8*	*76*	85.1	83	84.8	78	85.2	88	85.0	**86**	85.4	87
Materials	52	163	13	25	62	*85.8*	*67*	84.8	87	85.4	72	84.5	93	84.9	**87**	84.1	94
Resource	28	134	9	34	57	*83.3*	*92*	84.7	89	83.9	89	85.3	87	84.8	**88**	86.3	83
Environment	40	209	10	33	56	*83.0*	*80*	84.6	91	84.2	88	84.9	90	84.6	**89**	85.3	88
Electronics	1	192	17	36	47	*83.3*	*95*	84.2	93	83.7	92	84.6	91	84.4	**90**	85.2	90
Marine & earth	40	104	12	21	67	*82.5*	*99*	85.0	85	83.3	97	85.7	84	84.4	**91**	86.7	80
Materials	33	153	15	22	63	*82.3*	*100*	84.7	88	83.1	99	85.4	85	84.3	**92**	86.4	81
Agriculture	74	178	6	26	67	*82.8*	*96*	84.3	92	83.8	91	84.5	92	84.2	**93**	85.0	92
Materials	85	80	8	30	63	*84.3*	*87*	84.0	94	83.6	95	84.2	94	83.9	**94**	84.5	93
Electronics	36	151	21	26	54	*85.8*	*64*	83.7	95	84.4	87	83.4	97	83.7	**95**	82.9	98
Transportation	26	158	6	22	73	*84.5*	*93*	83.6	96	83.7	94	83.6	95	83.6	**96**	83.6	95
Environment	39	198	19	25	56	*83.8*	*81*	83.5	97	83.7	93	83.5	96	83.5	**97**	83.4	96
Life Science	33	82	6	32	62	*83.8*	*94*	83.4	98	83.6	96	83.2	98	83.4	**98**	82.9	97
Electronics	37	134	25	24	51	*83.5*	*84*	83.0	99	83.3	98	82.8	99	83.0	**99**	82.6	99
Manufacturing	24	120	8	16	77	*83.8*	*98*	81.6	100	82.6	100	81.2	100	82.1	**100**	80.7	100

Appendix 4: Presentation slides

Discussion of importance index in technology foresight

Discussion of importance index in technology foresight

- Introduction
- Importance index by considering the degree of expertise
- Rank comparing of top 100 important topics
- Grouping the priority topics
- Summary

1 Introduction

- The important index formula:

$$I_{index}=(100*N_{high}+50*N_{medium}+25*N_{low})/N_{all}$$

- Three questions were raised when using above formula
- *(1) Was the topic's importance credible if the proportion of high degree of expertise was quit low?*
- *(2) Should we consider the different contribution of expertise in calculating the importance index?*
- (3) *Is there any way to replace the ranking? Generally, it is difficult to balance the opinions from different technology fields when aggregating all the topics.*

2 Importance index by considering the degree of expertise

- **2.1 The formula**

$$I_{index}=I_H*W_H+I_M*W_M+I_L*W_L$$

Where I_H, I_M and I_L are the importance index of high, medium and low degree of expertise respectively, and W_H, W_M and W_L are the relative weighted values, where

$$W_H+W_M+W_L=1$$

- $I_H=(100*N_{11}+50*N_{12}+25*N_{13})/T_H$
- $I_M=(100*N_{21}+50*N_{22}+25*N_{23})/T_M$
- $I_L=(100*N_{31}+50*N_{32}+25*N_{33})/T_L$

Importance / Degree of expertise	High	Medium	Low	Unnecessary	Total
High	N_{11}	N_{12}	N_{13}	N_{14}	T_H
Medium	N_{21}	N_{22}	N_{23}	N_{24}	T_M
Low	N_{31}	N_{32}	N_{33}	N_{34}	T_L

2.2 Weighted values

- two factors should be considered:

  —— *The percentage of high, medium and low degree of expertise*

  —— *The contributions of high, medium and low degree of expertise.*

- the weighed values can be calculated by
- $W_H=K_1*T_H/T_{all}$
- $W_M= K_2*T_M/T_{all}$
- $W_L= K_3*T_L/T_{all}$

- Where K_i (i=1,2,3) called the convert coefficients, K_1=1 for high degree of expertise, K_2 for medium degree, K_3 for low degree, and K_1 K_2 K_3. Where $T_{all}= T_H+ K_2*T_M + K_3*T_L$, called the number of converted responses.

- The formula of important index will be

$$I_{index}=(100*N_{11}+50*N_{12}+25*N_{13}+ K_2(100*N_{21}+50*N_{22}+25*N_{23})+ K_3(100*N_{31}+50*N_{32}+25*N_{33}))/ T_{all}$$

if $K_1=K_2=K_3=1$, the coefficient matrix of N_{ij} (i=1,2,3, j=1,2,3) show as fellows

Importance / Degree of expertise	High	Medium	Low
High ($K_1=1$)	100	50	25
Medium ($K_2=1$)	100	50	25
Low ($K_3=1$)	100	50	25

If $K_1=1$, $K_2=0.75$, $K_3=0.5$, the coefficient matrix

Importance / Degree of expertise	High	Medium	Low
High ($K_1=1$)	100	50	25
Medium ($K_2=0.75$)	75	37.5	18.75
Low ($K_3=0.5$)	50	25	12.5

If $K_1=1$, $K_2=0.5$, $K_3=0.25$, the coefficient matrix

Importance / Degree of expertise	High	Medium	Low
High ($K_1=1$)	100	50	25
Medium ($K_2=0.5$)	50	25	12.5
Low ($K_3=0.25$)	25	12.5	6.25

- If $K_3=0$, it means the opinion of low degree of expertise was not included.

2.3 Convert coefficients K_i

- Rank comparing by six kinds of K_i in standard topic group

	Order Difference					
	(K_1=K_2=K_3=1)	(K_1=K_2=1, K_3=0)	(K_1=1, K_2=0.75, K_3=0.5)	(K_1=1, K_2=0.75, K_3=0)	**(K_1=1, K_2=0.5, K_3=0.25)**	(K_1=1, K_2=0.5, K_3=0)
Total	126	Standard	80	36	**46**	76
Maximum	14		11	3	**6**	10

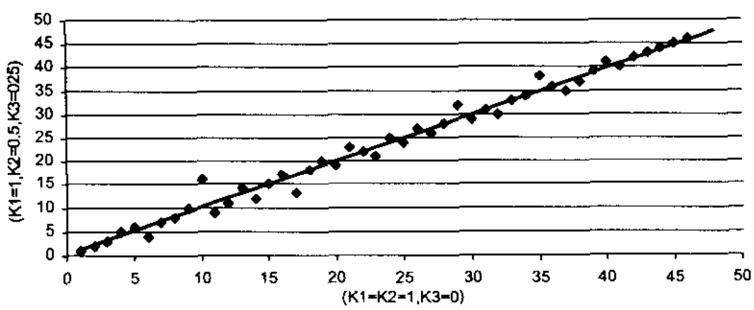

Fig.1 Rank comparing in standard topic group (Group one)

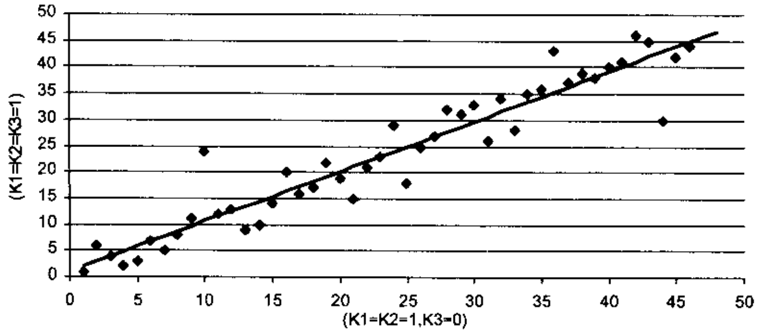

Fig.2 Rank comparing in standard topic group (Group two)

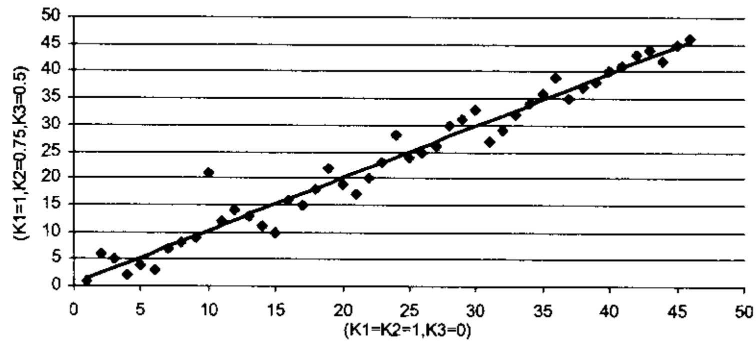

Fig.3 Rank comparing in standard topic group (Group three)

3. Rank comparing of top 100 important topics

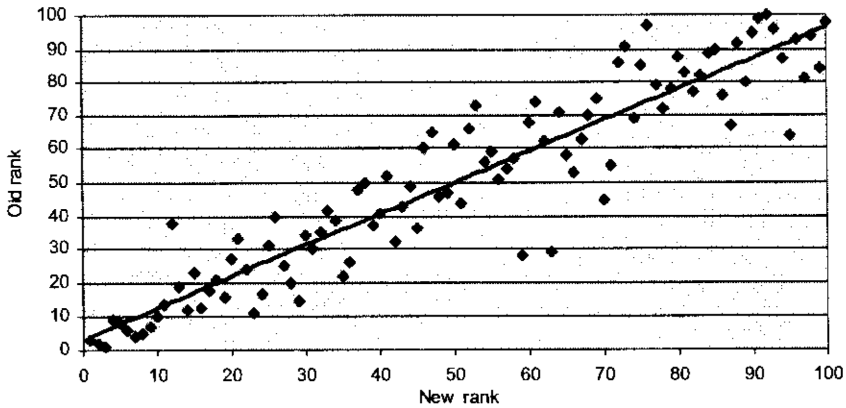

Fig. 4 The relationship between new and old rank in top 100 important topics

The comparativeness of top 100 important topics between new rank and old rank

Order difference	0	1	2	3	4	5	6-10	11-15	16-20	21-25	25-30	>30
Number of the topics	5	6	14	11	5	9	23	15	6	2	1	3

The comparativeness between "Old" and "New" importance index by fields

Fields (Number of topics)	Importance Index		
	Old	New	Difference
Total (100)	**87.1**	**88.2**	**1.1**
Information and Communication (7)	88.1	89.5	1.4
Electronics (12)	86.1	87.9	1.8
Life Sciences (21)	88.5	89.5	1.0
Health and Medical Care (3)	86.7	89.5	**2.8**
Agriculture, Forestry, Fisheries and Food (9)	86.2	87.6	1.4
Marine Science and Earth Science (7)	88.7	89.9	1.2
Space (2)	85.5	88.3	**2.8**
Resource and Energy (5)	86.8	88.4	1.6
Environment (5)	87.4	87.8	0.4
Material and Processing (10)	86.1	86.6	0.5
Manufacturing (6)	86.2	87.3	1.1
Distribution (2)	85.0	86.7	1.7
Business and Management (3)	84.7	87.2	**2.5**
Urbanization and Construction (5)	86.8	87.6	0.8
Transportation (2)	85.5	86.1	0.6
Service (1)	94.0	94.8	0.8

4. Grouping the priority topics

- Question: it is very difficult to compare the topics in different fields
- Possible solution: Grouping

The relative importance index was introduced when aggregating all the topics

$$I_{index}' = I_{index} * 100/(\text{Maximum of importance index in each field})$$

Fields	Number of topics in old top 100 topics	Number of topics in new top 100 topics	Number of topics changed in top 100 topics numbers	Topics*
Total (100)			**8**	
Information and Communication	7	6	-1	*10 removed*
Electronics	12	12	0	
Life Sciences	21	18	-3	*33, 88, 13 removed*
Health and Medical Care	3	4	1	**6 added**
Agriculture, Forestry, Fisheries and Food	9	11	2	**8, 16 added**
Marine Science and Earth Science	7	5	-2	*33, 40 removed*
Space	2	3	1	**8 added**
Resource and Energy	5	3	-2	*28, 13 removed*
Environment	5	6	1	**29 added**
Material and Processing	10	11	1	**3 added**
Manufacturing	6	6	0	
Distribution	2	2	0	
Business & Manage.	3	4	1	**5 added**
Urbanization and Construction	5	5	0	
Transportation	2	3	1	**30 added**
Service	1	1	0	

Fields	Topics				
	Group 1 (<98 and ≤100)	Group 2 (<96 and ≤98)	Group 3 (<94 and ≤96)	Group 4 (<92 and ≤94)	Group 5 (<90 and ≤92)
Total (100)	**26**	**19**	**20**	**29**	**6**
Information and Communication	19, 18		50, 79	65	12
Electronics	6, 25	10	13, 22, 36	7, 18, 29, 11, 37	1
Life Sciences	1, 38, 65	23, 37, 11, 27, 82	17, 24, 5, 14, 16, 31	9, 59, 72	87
Health and Medical Care	4	5	9	6	
Agriculture, Forestry, Fisheries and Food	1, 49	62, 76, 73, 75, 79	63	74, **8**, **16**	
Marine Science and Earth Science	55	51		13, 63, 57	
Space	20		29	**8**	
Resource and Energy	49			53	75
Environment	21, 22, 38			39, 40	**29**
Material and Processing	99, 75, 76	62	52, 53, 86	35, 85, 33	**3**
Manufacturing	40	39, 42	41	19, 24	
Distribution	14	9			
Business and Management	25, 26	11		**5**	
Urbanization and Construction	26	4	3	1, 14	
Transportation	29		26	**30**	
Service	31				

The comparativeness of old and new Important index by fields

Fields	Importance		Relative importance	
	Index	Rank	Index	Rank
Total	61.2		67.4	
Life science	72.6	1	78.1	1
Electronics	66.2	2	72.8	2
Environment	65.5	3	72.8	3
Manufacturing	65.4	4	72.6	4
Agriculture	62.4	7	70.1	5
Materials and processes	62.7	6	69.6	6
Business	59.5	**10**	69.2	7
Marine and earth	63.6	*5*	67.0	8
Health and medical care	59.3	**11**	66.6	9
Information	60.5	9	65.0	10
Resource and energy	60.8	*8*	64.6	11
Urbanization	57.5	12	63.2	12
Transportation	55.1	14	62.7	13
Space	53.1	15	60.3	14
Services	55.6	*13*	59.1	15
Distribution	46.6	16	54.2	16

5. Summary

- In priority setting, the degree of expertise should be considered in calculating the importance index.
- In priority setting, if the percentage of high degree of expertise was quite low, we should increase the number of high experts, otherwise don't include these topics.
- The grouping way was probably the method to balance the different opinions from the different fields, and the relative important index can reduce the difference of assessing standard of the expert's groups.